METHOD OF TESTING SPECIMENS OF MARBLE.

BY PROF. FRANK D ADAMS.

In the SCIENTIFIC AMERICAN for April 23, 1898, an account was given of some researches on the Flow of Rocks, which were being carried on by Prof. Adams and Prof. Nicholson, at McGill University, in Montreal. The rock employed for purposes of experiment was Carrara marble, small columns of which were inclosed in stout tubes of wrought iron, constructed after the manner of ordnance by wrapping long strips of Lowmoor iron around a bar of soft iron and welding the strips to the bar as they were rolled around it. The core of soft iron composing the bar is then bored out, leaving the iron tube, into which the marble column was very accurately fitted. The pressure was applied through heavy steel pistons fitted into either end of the tube, making use of a hydraulic accumulator by which the ordinary pressure of the water mains—namely, 130 pounds to the square inch—could be increased to any desired extent, pressures up to 13,000 atmospheres, for instance, being frequently applied. Making use of this machine, it was shown that columns of marble, when inclosed in the iron tubes as above described, might, at the ordinary temperature, be deformed, the marble column being squeezed down and the inclosing iron tube bulged out; the marble remaining throughout the process compact and solid.

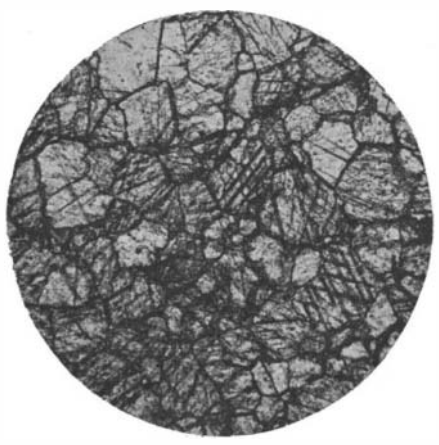
Since the appearance of the article in question, experimental work along this line has been continued, additional presses have been constructed, new apparatus installed, and many new and important results obtained.

The machines, as at present arranged, are shown in our engraving. The three presses are set up side by side, but at different levels, to allow free play to the long screws which afford an accessory means of increasing the hydraulic pressure in the cylinders. The cylinders and additional intensifiers, with all their complicated system of pipes and valves—by which the water pressure from the main is transferred to the oil which fills the whole system, and through it to the machine, and by which the pressure may be maintained constant at any value for any desired time—are shown on the right of the photograph. The apparatus is also arranged so that water under any desired pressure may be passed through the rock itself while it is being squeezed. The rock may be heated to any desired temperature by means of a gas flame, or a gasoline blast, while undergoing compression. The hydraulic pump in front is capable of developing a pressure of 10,000 pounds to the square inch, and may be used either in connection with the machine or for forcing water through the rock itself.

In the machine on the left a marble column, inclosed in its iron tube, is in position ready for the application of the pressure to deform it at the ordinary temperature ("cold dry squeeze"). The machine in the center is arranged for a "hot dry squeeze," that is, for an experiment in which the rock shall be deformed while heated to 300 degrees C. or 400 degrees C. The heat is supplied by the Bunsen burner shown in the photograph, the heated gases circling about within a massive iron casting which incloses the iron tube containing the marble, without coming in contact with the latter except at the ends—space being left within the casting to allow for the bulging of the iron tube when the pressure is applied. The wires of the platinum thermometer for measuring the temperature pass into the casting on the left side, through the fire-clay tube shown in the photograph, and are brought out almost in contact with the iron tube inclosing the marble. Before the experiment is commenced the whole apparatus is, of course, covered with asbestos to prevent loss of heat. This, however, was removed before the photograph was taken, in order that the arrangement of the parts might be clearly shown.

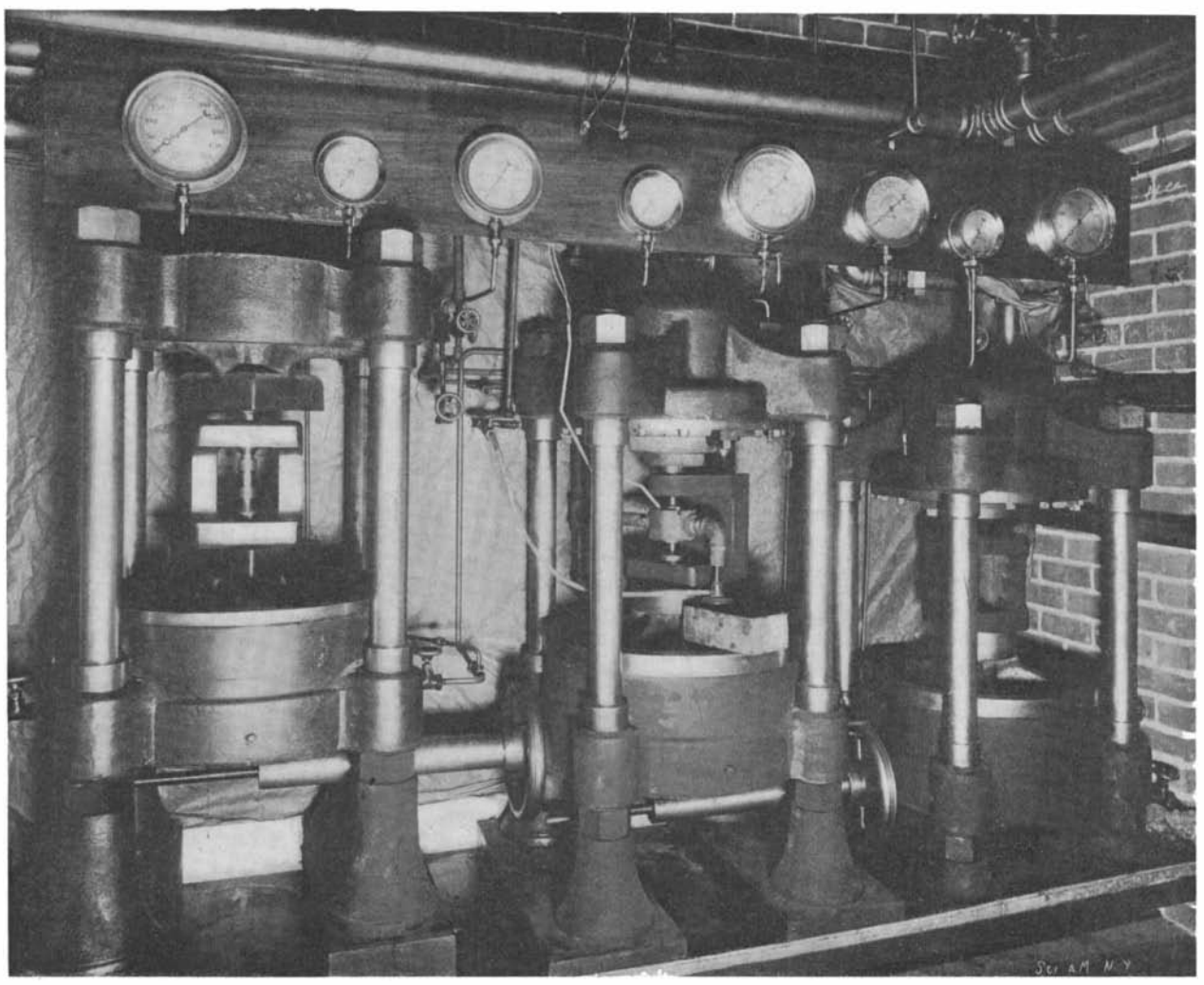
Another appliance is employed for producing a "hot wet squeeze," in which the rock, while heated, is strongly compressed, water at the same time being forced through it at a pressure of several hundred pounds to the square inch. By means of the machines fitted with these accessories, Carrara marble has been deformed, not only when cold and dry, but when heated to 300 degrees C. and to 400 degrees C. when dry, and heated to 300 degrees C. while water was being forced through it, the time occupied by the experiments being from 10 minutes to 64 days.

Micro-Photograph of Carrara Marble Before Compression.



Micro-Photograph of Carrara Marble after Deformation at 300° C., Showing the Flattening of the Calcite Grains.

On the completion of the experiment, the bulged tube containing the marble was slit through longitudinally along lines opposite to one another. The marble within was found to be still firm and compact, holding the respective sides of the tube, now completely severed from one another, so firmly together that it was found impossible, without mechanical aids, to tear them apart. By means of a steel wedge driven in between them, however, they could be separated, but only at the cost of splitting the marble through longitudinally. The half-columns of the marble, now deformed, generally adhered so firmly to the tube that it was necessary to spread the latter in a vise in order to set them free.



PRESSES FOR MAKING RESEARCHES ON THE FLOW OF ROCKS.

The deformed marble was then tested in compression by means of an Emery testing machine, and its strength compared with that of half columns of uncrushed marble cut to the same form. Thin sections were also cut from the deformed marble, and their microscopic character compared with that of the uncrushed rock.

It was found that when the marble was deformed in the cold, after deformation it would bear a load of as much as 5,350 pounds per square inch. This, however, was only about one-half the crushing weight of the original rock, which is about 12,000 pounds per square inch. The predominant structure of the deformed rock, under the microscope, was found to be what is known as a cataclastic structure—that is to say, the calcite crystals composing the marble had been broken and the fragments had passed over one another, but had remained so firmly pressed together that the rock still retained its solidity. The strength of the rock when deformed at a temperature of 300 degrees C., however, rose to 10,652 pounds per square inch; that is to say, it was nearly as strong as the original rock, and under the microscope it was seen to have moved, not by the breaking of the individual crystals composing the rock, but by a flattening of each crystal, owing to movements on twinning and gliding planes. This is precisely the nature of the movement in the case of iron or any other metal when it is hammered or rolled, as has been shown by the recent investigations of Ewing and Rosenhain. The marble "flows" under these conditions just as a billet of iron does when heated and rolled.

Our engravings show microphotographs of a section of the marble before squeezing, and the same marble after it has been deformed at 300 degrees C. The flattening of the grains can be distinctly seen.

When the heated marble was deformed, while at the same time water was being forced through it, the movement was of the same character as that just described, but the marble was found to be actually stronger than the original rock.

These experiments have an important bearing on the nature of the movements which take place in rocks when they are folded up into mountain ranges, and they are now being continued with granites and other harder rocks.

Areas of Future Cities.

Writing in the Fortnightly Review, H. G. Wells observes that we are "on the eve of a great development of centrifugal possibilities. And since it has been shown that a city of pedestrians is inexorably limited by a radius of about four miles, and that a horse-using city may grow out to seven or eight, it follows that the available area of a city which can offer a cheap suburban journey of thirty miles an hour is a circle with a radius of thirty miles. And is it too much to expect that the available area for even the common daily toilers of the great city of the year 2000, or earlier, will have a radius very much larger even than that?

Now, a circle with a radius of thirty miles gives an area of over 2,800 square miles, which is almost a quarter that of Belgium. But thirty miles is only a very moderate estimate of speed, and the reader will probably agree that the available area for the commuter of to-day will have a radius of over 100 miles and be almost equal to the area of Ireland. The radius that will sweep the area available for such as now live in the outer suburbs will include a still vaster area. Indeed, it is not too much to say that the London citizen of the year 2000 A. D. may have a choice of nearly all England and Wales south of Nottingham and east of Exeter as his suburb, and that the vast stretch of country from Washington to Albany will be all of it 'available' to the active citizen of New York and Philadelphia before that date."

Stonehenge has been cut off from Salisbury Plain by a wire fence and a charge of a shilling is made to visitors who desire to pass the barrier in order to get a near view of the monument.